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Biodiversity of cyclopoid copepods in Thailand — with a description of *Afrocyclops henrii* sp.n.

Биологическое разнообразие циклопов Таиланда с описанием *Afrocyclops henrii* sp.n.

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КЛЮЧЕВЫЕ СЛОВА: Cyclopoida, Таиланд, систематика, биогеография, *Afrocyclops henrii* sp.n.

ABSTRACT. A series of samples of littoral zooplankton collected in different parts of Thailand contained 43 species and subspecies of Cyclopids. 26 among these are new records to the fauna of Thailand that significantly increased previous list of 16 species known in the country. *Afrocyclops henrii* sp.n. from cold water mountain stream in Southeast Thailand is described. Fauna of Cyclopids in Thailand presents a mix of elements with different geographical origin. *Afrocyclops henrii* sp.n., *Eucyclops euacanthus* (G.O.Sars, 1909), *Tropocyclops tenellus* (G.O. Sars, 1909), *T.confinis* (Kiefer,1930), *Mesocyclops ogunnus* Onabamiro, 1957 represent Africain elements in the fauna. *Eucyclops microdenticulatus* Lindberg, 1940 and *Thermocyclops maheensis* Lindberg, 1941 represent Indo-Iranian fauna. *Eucyclops arcanus* Alekseev, 1990, *E. pacificus* Ishida, 2000, *Ectocyclops polyspinosus* Harada, 1930 had been known from Central and Far East Asia. *Macrocyclops neuter* Kiefer, 1931, seems like the only endemic of Southeast Asia. *Cryptocyclops linjanticus* (Kiefer, 1928) is widely distributed in south of Eurasia and North Africa. *Macrocyclops albidus (*Jurine, 1820), *M. fuscus* (Jurine, 1820), *Tropocyclops prasinus* (Fischer, 1860), *E. serrulatus* (Fischer, 1851) and *T. crassus* (Fischer, 1851) described at first in Europe, are close to be named as cosmopolites. In Thailand meanwhile they are differed in small details from the type descriptions and their true zoogeographical status have to be studied. We define the continental Cyclopoid fauna in Thailand as a fusion of Afro-Indo-Eurasian elements. This faunistic mixture possibly reflects the hydrological and geological history of this territory and presents additional difficulties for taxonomists. Updated keys for freshwater cyclopids of Thailand and adjacent territories are supplemented.

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РЕЗЮМЕ. В пробах литорального зоопланктона, собранного в различных районах Таиланда были обнаружены 43 вида и подвида циклопов, включая 25 новых видов для страны и один новый вид для науки. Ранее для водоемов Таиланда было известно лишь о 16 видах циклопов. *Afrocyclops henrii* sp.n. был обнаружен в холодноводном горном ручье на Северо-западе страны. Анализ фауны с биогеографических позиций позволяет выявить несколько элементов различного происхождения. *Afrocyclops henrii* sp.n., *Eucyclops euacanthus* (G.O. Sars, 1909), *Tropocyclops tenellus* (G.O. Sars, 1909), *T.confinis* (Kiefer, 1930), *Mesocyclops ogunnus* Onabamiro, 1957 представляют собой элементы Африканской фауны. *Eucyclops microdenticulatus* Lindberg, 1940 *and Thermocyclops maheensis* Lindberg, 1941 имеют Индоиранское происхождение. *Eucyclops arcanus* Alekseev, 1990, *E. pacificus* Ishida, 2000, *Ectocyclops polyspinosus* Harada, 1930 были описаны из Центральной Азии и водоемов Дальнего Востока. *Macrocyclops neuter* Kiefer, 1931, по-видимому, единственный эндемик Юго-Восточной Азии. *Cryptocyclops linjanticus* (Kiefer, 1928) широко распространен в водоемах Евразии и Северной Африки. Наконец, *Macrocyclops albidus (*Jurine, 1820), *M. fuscus* (Jurine, 1820), *Tropocyclops prasinus* (Fischer, 1860), *E. serrulatus* (Fischer, 1851) и *T. crassus* (Fischer, 1851) были первоначально описаны из Европы, но в дальнейшем были признаны видами с космополитическим распространением. Экземпляры этих видов из Таиланда имеют некоторое отличие от европейских особей. Таксономическое значение этих отличий пока остается неясным. Смесь различных зоогеографических элементов в фауне Таиланда, по-видимому, отражает геологическую и гидрографическую историю этой страны. Приводится подробный ключ для определения видов циклопов из Таиланда и прилегающих к нему стран.

Introduction

Freshwater cyclopids are poorly studied in the tropics of Asia, so in Thailand [Alekseev, 2002; Sanoamuang, 2003]. *Cryptocyclops bicolor* (Sars, 1863), *Thermocyclops crassus* (Fischer, 1853) and

Tropocyclops prasinus (Fischer, 1860) were the first records to the Thailand cyclopoid fauna according to Bricker *et al*. (1978). Up to now, therefore, the list of cyclopids for this country contains only 16 species [Sanoamuang 1998, 2003]. If compared to the biodiversity of the calanoid group (37 species) of Copepoda there exists a remarkable difference of our knowledge of the copepod fauna in Thailand between these two suborders [Sanoamuang 2003].

Most of the cyclopid species found in Thailand (60%) belong to the plankton whereas at a global scale, tropical cyclopids dominate littoral and benthic habitats [Dussart & Defaye, 1985]. In this context it is remarkable that not a single harpacticoid species from the limnetic benthos is known from this country. We conclude that the low biodiversity known from Thailand cyclopoids is caused by little sampling and research efford and methods that were chosen to target planktonic representatives.

So, the main goal of this study was to collect littoral and meiobenthic samples in addition to zooplankton and to study biotopes with little research efford as yet, like streams, wells, and estuaries where new cyclopid representatives could be expected.

Material and methods

We collected copepods in near shore areas in 20 freshwater and brackish water habitats in northeast, central and southern Thailand in February 2003 (Table 1). The most remarkable site was a stream in Nam Nao National Park, the only place in the country with surface water temperatures below 16°C in winter time. For sampling we used a triangular hand net with 150 µm mesh size and a towel net with 100 µm mesh size. At shallow locations (less than 0.1 m depth) we filtered 50 l of water through a net. At wells we pumped 100 l of water *via* a funnel through a net of 60 µm mesh size. In rivers and streams we washed leaf and roots of water-swimming plants inside the hand net (e.g. *Eichhornia crassipes*, *Salvinia natans*), water roots of trees and bamboo, stones covered with moss to explore possible refuges of cyclopids against fish. After washing large size leafs, roots and other remains were taken from the net, the remaining sample was gently rinsed to wash out mud and than placing the remaining material in one or two 100 ml plastic tubes. Samples were immediately preserved in 2–4% formaldehyde or 70% ethanol and sorted under a stereoscopic microscope Olympus-SZX in one or two days after collection. Any new copepod species was dissected and placed on a separate slide in pure glycerol, than covered with a cover glass and surrounded with DePeX mounting medium.

For this study we also surveyed some samples from an intensive zooplankton collection of the Biodiversity Center of Khon Kaen University. Methods and sampling sites for this collection have been described by Sanoamuang [2003].

Examination and drawing of species or taking their video images was done with a compound microscope Olympus BX-51. After mounting, the figures were reduced in size than scanned and their images were computer optimized by the Adobe Photoshop program. Slides and video images of each species were prepared in duplicate and spitted between authors.

For species identification we used a preliminarily prepared key of cyclopid species known from South East Asia and several recent revisions from this area or from the world copepod fauna [Alekseev, 2002; Holynska, 2000; Karaytug, 1999].

Results and discussion

We found 45 cyclopid species with 28 species being new for Thailand and *Afrocyclops henrii* n.sp. being new for science. Cyclopids belong to two families (family Oithoninae new for Thailand) and to 15 genera (7 genera represent new records for Thailand) (Table 2). We present the description of the female of *Afrocyclops henrii* sp.n. and systematic and biogeographic comments on the most interesting cyclopoid species.

Afrocyclops henrii Alekseev et Sanoamuang **sp.n.**

MATERIAL EXAMINED. Three females collected on 1st February 2003 from a mountain stream in Nam-Nao National Park.

One dissected female (holotype) placed in glycerol surrounded with Canada balsam was deposited in the Federal Collection of the Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia (N 55026). Two undissected females (N 55027) are stored in glycerol in the same collection.

TYPE LOCALITY. The mountain stream in Nam-Nao National Park, North-East Thailand.

ETYMOLOGY. This species is named after Professor Henri Dumont, University of Gent, Belgium, to honour his extensive contributions to the study of the taxonomy and ecology of aquatic invertebrates, particularly in the tropics.

DESCRIPTION. Female holotype: Body length without caudal setae 764 µm, with caudal setae 1104 µm.

Cephalosome as long as wide, with the maximum width close to the next segment connection (Fig. 1A). Last segment of prosome with 7 long hairs at its lateral margins. Genital double somite 1.3 times as long as wide, with small ellipse-like seminal receptacles (Fig. 1B). This somite with 2 cavities at dorsolateral side clearly seen from dorsal position bearing rudimentary legs 6, *i.e.* three small processes with 1 long hair each.

Caudal ramus about 5.2 times as long as wide, without serrula at the outer edge and six setae at distal part of ramus. Lengths proportions beginning from the outermost terminal seta: 1./5.75/8.75/1.1. Dorsal seta about two times as long as the outermost seta and the lateral seta about one third of the length of outer setae.

Antennule of 12 segments, short but reaching first free somite, without a hyaline membrane at caudal edge of the

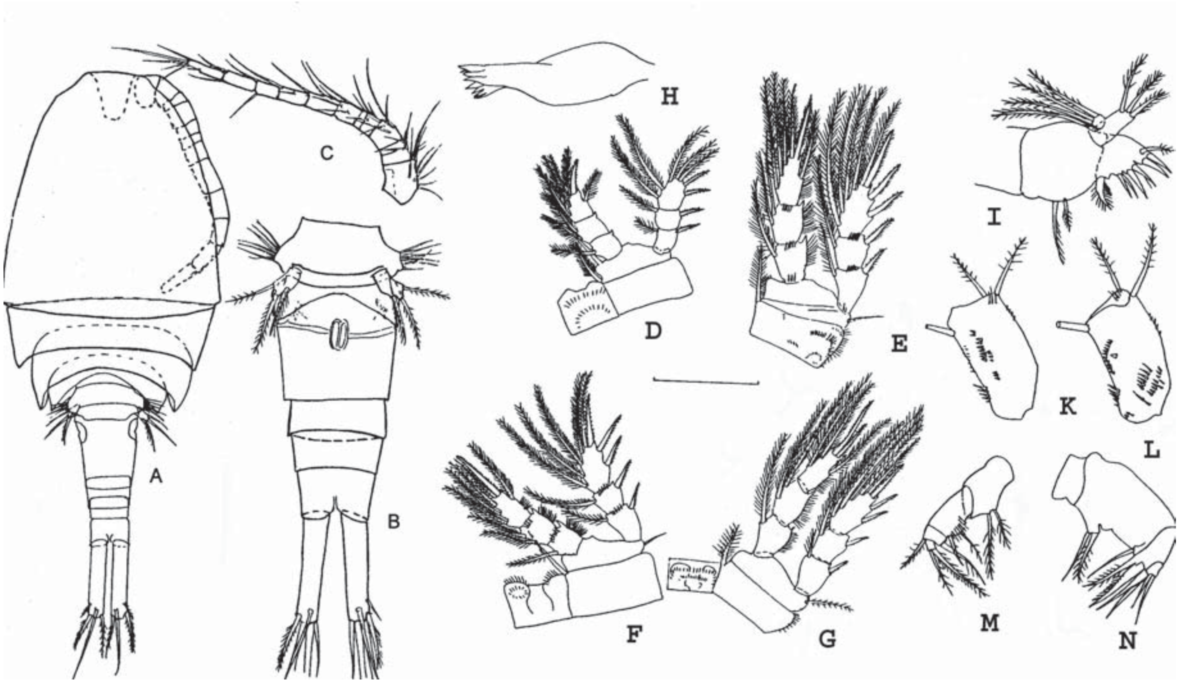


Fig. 1. *Afrocyclops henrii* sp.n. female, Nam Nao National Park, Thailand: A — habitus, dorsal; B — urosome, ventral; C — antennula; D–G — leg 1–4; H — mandible; I — maxillule; K — basipod of antenna, caudal; L — basipod of antenna, frontal; M — maxiliped; N — maxille. Scale bars: A — 100 mcm; B–G, M, N — 50 mcm; I, H — 40 mcm; K, L —25 mcm.

Рис. 1. *Afrocyclops henrii* sp.n., самка, Национальный парк Нам Нао, Таиланд: A — общий вид дорзально; B — уросома, вентрально; C — антеннула; D–G — ноги 1–4-й пар; H — мандибула; I — максиллула; K — базипод антенны, каудально; L — базипод антенны, фронтально; M — максиллипеда; N — максилла. Масштаб: A — 100 mcm; B–G, M, N — 50 mcm; I, H — 40 mcm; K, L —25 mcm.

three segments (Figs 1C, 3A). Setation of antennular segments begining from first: 8/4/2/5/3/1/2/3/2/2/2/7.

Antenna basipode at caudal side with a group of 3 hair-like spinules near to the insertion plane of the two setae, two parallel lines of spinules placed diagonally in the central part and with two groups of spinules and hairs on the lateral sides (Fig. 2B). At frontal side this segment bears 4 groups of 15–17 relatively small spinules in the central part and two lateral groups (Fig. 2A).

Gnathobase of mandible with 8 teeth, rudiment of the endopodal segment with 2 long setae and 1 short seta (Fig. 2D). Maxillula with 6 strong teeth and 2 strong setae with long hair-like setae, 1 strong seta at the praecoxal arthrite; basal exite with 7 setae of different lengths (Fig. 2C).

Maxilla of four segments; coxa with a strong spine in the middle and a small seta and a strong spine at its distal end; basal endite with two very strong spines and small setae near the place of fusion of the rudimentary endopod, bearing 2 long spines, seta with long hairs and 2 hairless setae (Fig. 4C).

Maxilliped of 4 segments, praecoxa + coxa with 2 strong setae in the middle part and small setae at their distal end; basis with 2 setae of different length and a group of strong hairs along the insertion of the setae; first segment of endopod with 1 strong spine and a group of hair-like setae surrounding the rudimentary rest of the other segments of the endopod, bearing 1 strong spine and 2 hairless setae (Fig. 4D).

Swimming legs 1–4 with 3-segmented rami (Fig. 3B, C4; 4A, D). Distal segment of exopod of leg 1 with two spines and five setae; legs 2 and 3 with three spines and five setae. Distal segment of the endopod of legs 2–4 with a spine and five setae. Distal segment of endopod leg 4 elongated, 2.3 times as long as wide, with two strong spines at its end, inner spine 1.6 times as long as the outer spine (Fig. 3C).

Inner edge of the basis of legs 1–4 round-shaped with a group of hairs, with 1 strong spine. Coxae of legs 1–4 with 1 strong spine bearing dense hairs on lateral sides. Caudal side of coax in legs 3–4 with plenty of tiny spinules on the inner side and several groups of denticles and hair-like setae, as shown in Figure 3. Intercoxal sclerite between both legs 1 without depressions, with 2 rows of small hairs in its middle part and without hairs on its free caudal edge (Fig. 4A). The intercoxal sclerites of legs 2–4 also without depressions on their free edge and with 2 lines of hairs as shown in figures 3 and 4.

Rudimentary leg 5 is 1-segmented, with a rather strong knife-like inner spine and 2 setae, outer seta as long as spine, middle seta about 1.2 times as long as spine (Fig. 1B).

Egg sacs with 10–20 eggs each.

Male is unknown.

DIFFERENTIAL DIAGNOSIS. Genus *Afrocyclops* erected by Sars [1927] now includes 9 species with two subspecies in *A. gibsoni*. Only the latter species has been known outside Africa. Lindberg [1943] found *A. gibsoni* (Brady, 1904) in India and Kiefer [1933] described *A. g. abreviatus* from Java and Bali. The newly described *A. henrii* is the second species found in South East Asia. *Afrocyclops* is clearly separated from other congeners by characters like the very long dorsocaudal seta. From the most related *A. gibsoni abreviatus* (Kiefer, 1933) known from Java and Madagascar the new species does also differ by shorter caudal rami, shorter inner spines and longer distal

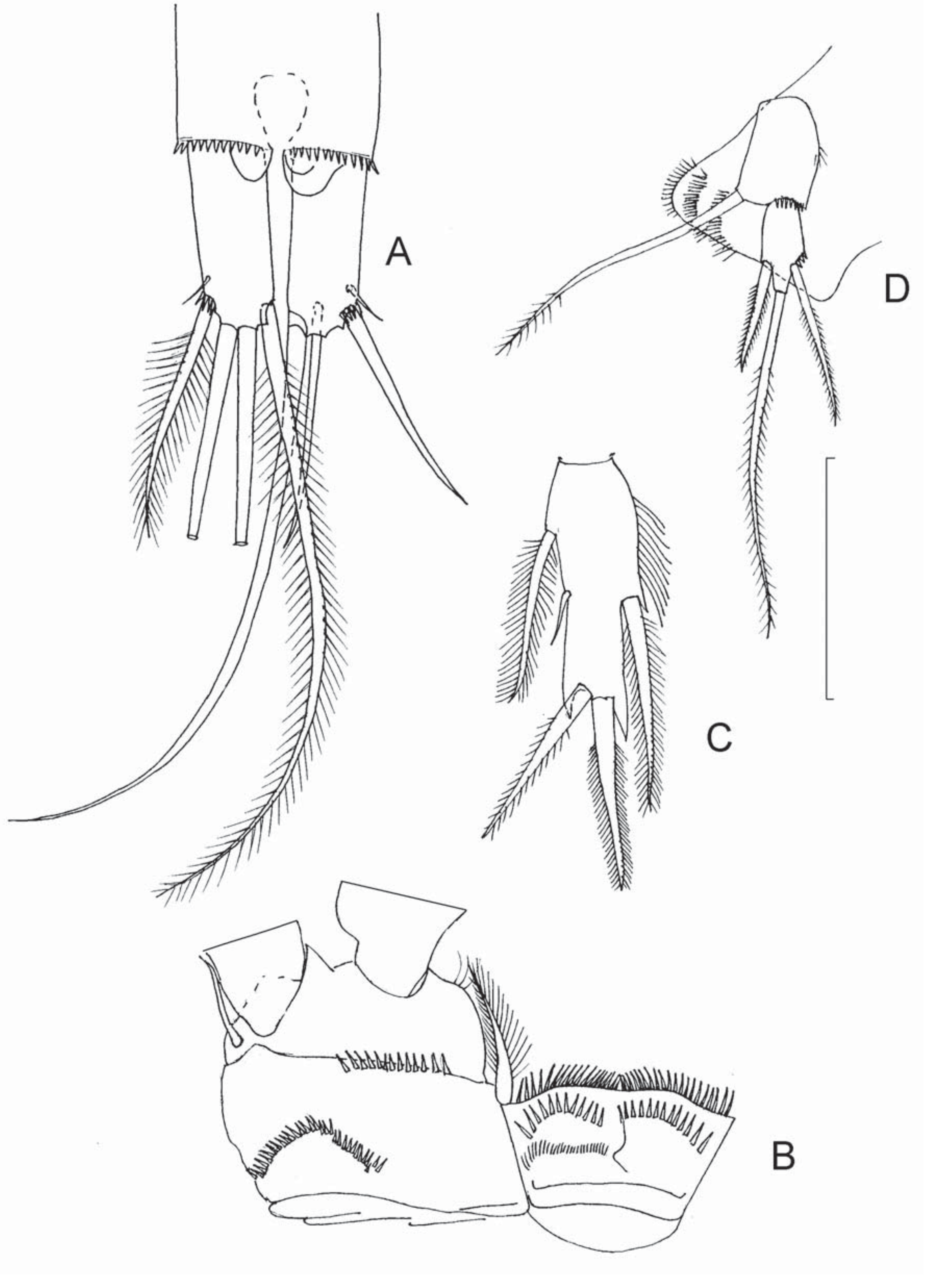


Fig. 2. *Macrocyclops albidus* (Jurine, 1820), female, Nam Nao National Park, Thailand: A — caudal rami, ventral; B — leg 4, caudal; C — distal segment of endopod leg 4; D — leg 5. Scale bars: A–C — 60 mcm.

Рис.2. *Macrocyclops albidus* (Jurine, 1820), самка, Национальный парк Нам Нао, Таиланд: A — каудальные ветви, вентрально; B — нога 4-й пары, каудально; C — дистальный сегмент эндоподита ног 4-й пары; D — нога 5-й пары. Масштаб: A–C — 60 mcm.

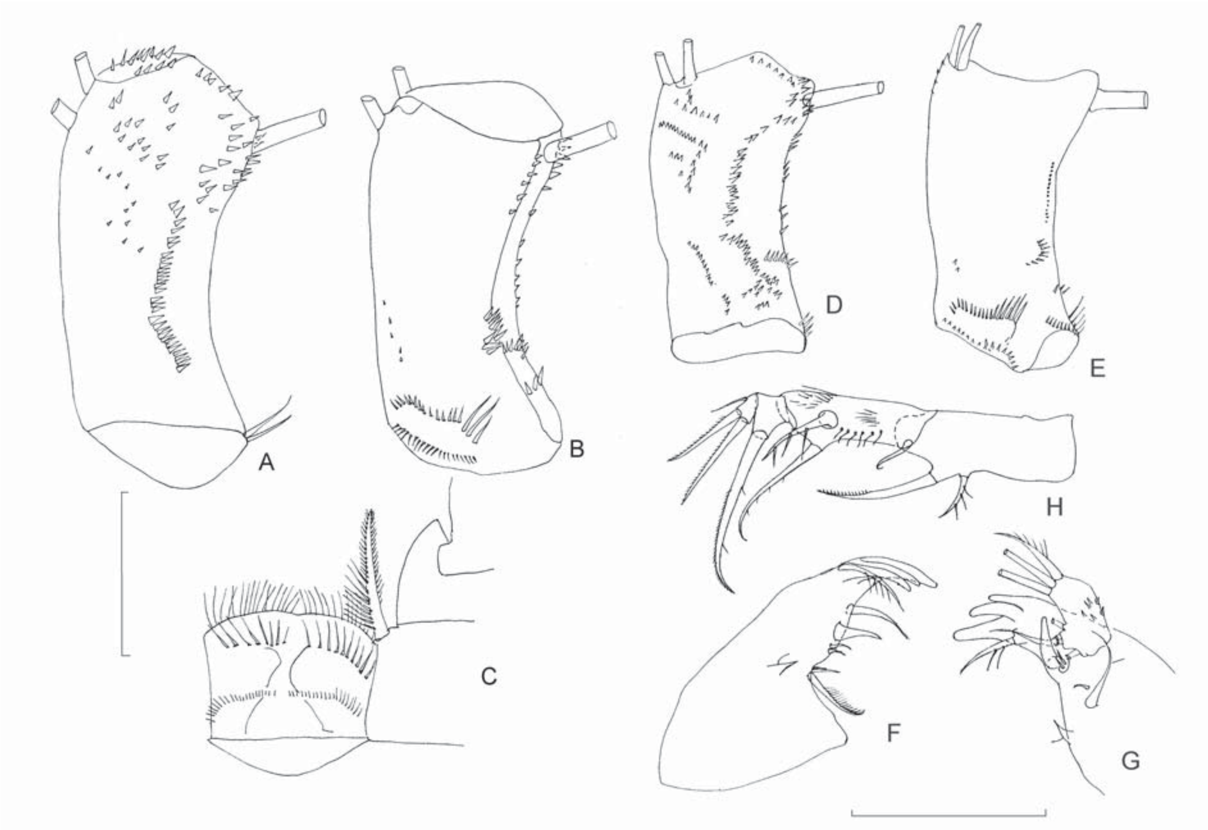


Fig. 3. *Macrocyclops albidus* (Jurine, 1820), female: A–C, F — Bergen vicinity, Norway; D, E, G, H — Nam Nao National Park, Thailand. A, D — basipod of antenna, frontal; B, E — basipod of antenna, caudal; C — connective coxal membrane leg 4; F — maxillule; G — maxillule with palp; H — maxilliped. Scale bars: A–B, D–E — 20 mcm; C, F, G, H — 40 mcm.

Рис. 3. *Macrocyclops albidus* (Jurine, 1820), самка: A–C, F — окрестности Бергена; D, E, G, H — Национальный парк Нам Нао, Таиланд. A, D — базипод антенны, фронтально; B, E — базипод антенны, каудально; C — соединительная пластинка ног 4-й пары; F — максиллула; G — максиллула с пальпой; H — максиллипеда. Scale bars: A–B, D–E — 20 mcm; C, F, G, H — 40 mcm.

setae of End P4. *A. pauliani* (Lindberg, 1951), is also closely related to the new species, bearing a relatively longer antennule, much longer caudal rami (L/W=6.7) and an inner caudal seta that is shorter than the outermost seta.

Comments on new records of other cyclopoids from Thailand

Family Oithoninae

Oithoninae are predominantly marine species, with few exceptions that are only sporadically found in brackish and freshwaters. Both new records for Thailand were collected in estuaries near the Gulf of Siam with salinities of 1–14 ‰ (see Table 1).

Genus *Limnoithona*

Limnoithona cf. *sinensis*

This taxon described from a Chinese lake, was later found in the Gulf of California, USA. It is tolerant to salinity and regarded as a brackish water form. In Thailand we found another copepod belonging to this taxon in the estuary of the river Mae Klon at a salinity of about 10 ‰. Other representatives were then identified in a sample from an irrigation channel in southern Thailand, that was kindly provided for us by Prof. Pornsilp Pholpunthin (see Table 1).

Genus *Oithona*

Oithona sp.

A single female of the species was found in an estuary in the vicinity of Bangkok and is likely to be new to science but we had not sufficient material to describe this particular species.

Genus *Halicyclops*

H. cf. *thermophilus*

This species usually occurs in estuaries and salt marshes. In northern Thailand it was collected in a temporary bog with fresh water at a distance of hundred miles from the sea shore (collected by Prof. Sanoamuang). Morphologically, it is close to *H. thermophilus* but we suggest that a taxon with so pecu-

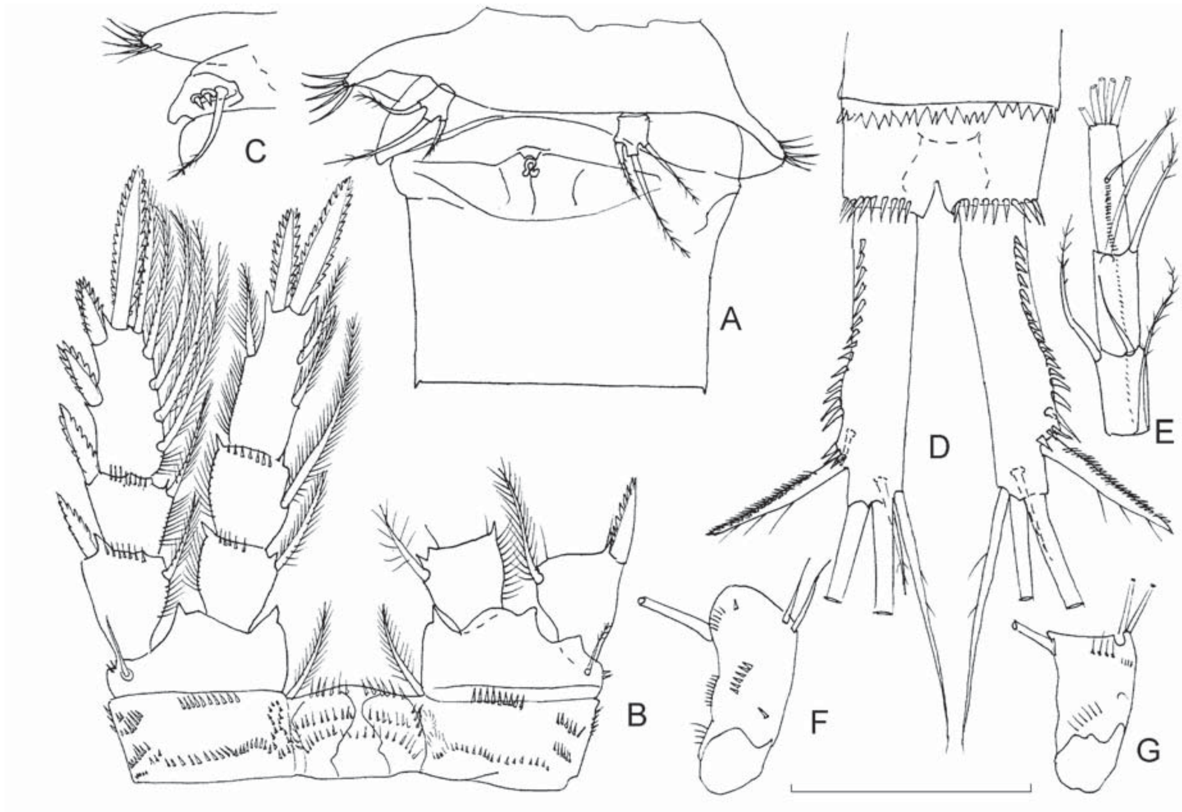


Fig.4. *Eucyclops euacanthus* (G.O. Sars, 1909) = *E. birmanus* Lindberg, 1949, female, The Nampong River, Thailand: A — genital double somite, ventral; B — caudal rami, ventral; C — rudimentary P6; D — leg 4, caudal; E — 11, 12 segments of antennule; F — basipod of antenna, frontal; G — basipod of antenna, caudal. Scale bars: A–G — 40 mcm.

Рис.4. *Eucyclops euacanthus* (G.O. Sars, 1909) = *E. birmanus* Lindberg, 1949, самка, река Нампонг, Таиланд: A — двойной генитальный сегмент, вентрально; B — каудальные ветви, вентрально; C — рудиментарные ноги 6-й пары; D — ноги 4-й пары, каудально; E — 11, 12-й сегменты антеннулы; F — базипод антенны, фронтально; G — базипод антенны, каудально. Масштаб: A–G — 40 mcm.

liar ecology might be new to science. From this habitat there was only a single partly destroyed female available for us.

Genus *Macrocyclops*

We found three species belonging to this genus that provides a new record for Thailand. All of them were collected in a stream in Nam Nao National Park. Comparisons of *M. albidus* (Jurine, 1820) and *M. fuscus* (Jurine, 1820) from Thailand with the same species from Norway (Bergen area) and Germany (Hamburg area) showed very few differences. The taxonomic significance of the differences is not clear for us and need a more detailed study (Figs 6–7). *M. neuter* Kiefer, 1931 from Thailand is similar to populations from Sri-Lanka and Burma according to Defaye & Dussart [1995].

Genus *Eucyclops*

E. microdenticulatus Lindberg, 1940 was recorded only once in Iran from where it was described. Our second record confirms validity of the species. *E. arcanus* Alekseev, 1989 described from South Siberia in Baikal area was later found in Japan [Ishida, 2000]. Thailand demarcates the most southern distribution of this species that is possibly widely distributed in Asia but was mixed with *E. serrulatus*.

In Thailand we also found a *Eucyclops* species closed to the descriptions both *E. birmanus* Lindberg, 1943 and *E.eucanthus* (Sars, 1906). A comparison of *E. eucanthus* from lake Malawi with *Eucyclops cf. birmanus* from Thailand let us conclude on morphological equivalence between these two taxa (Fig. 8). *E. birmanus* Lindberg, 1943 is possibly a younger synonym of *E. eucanthus* (Sars, 1906).

E. pacificus Ishida, 2001 is the first record of the species outside Japan (Fig. 9). This species possibly is also widely distributed in the Asian tropics and subtropics being very similar to *E. serrulatus*.

Genus *Tropocyclops*

This genus has not been revised as yet. We are faced with large morphological and size variability among *Tropocyclops* species in Thailand. Besides the cosmopolite *T. prasinus* (Fischer, 1860) known from India, China, Malaysia, Sri-Lanka, and Thailand (Boonsom 1984) we found two other species with African roots: *T. confinus* (Kiefer, 1930) and *T. tenellus. T. confinus* outside Africa was also found in India and Sri-Lanka [Defaye & Dussart, 1985].

For *T. tenellus* this is the first record outside Africa and Madagascar. We found this species at first in a well at 30-m depth, than in a small bog in Phon Paen National Park (see Table 2).

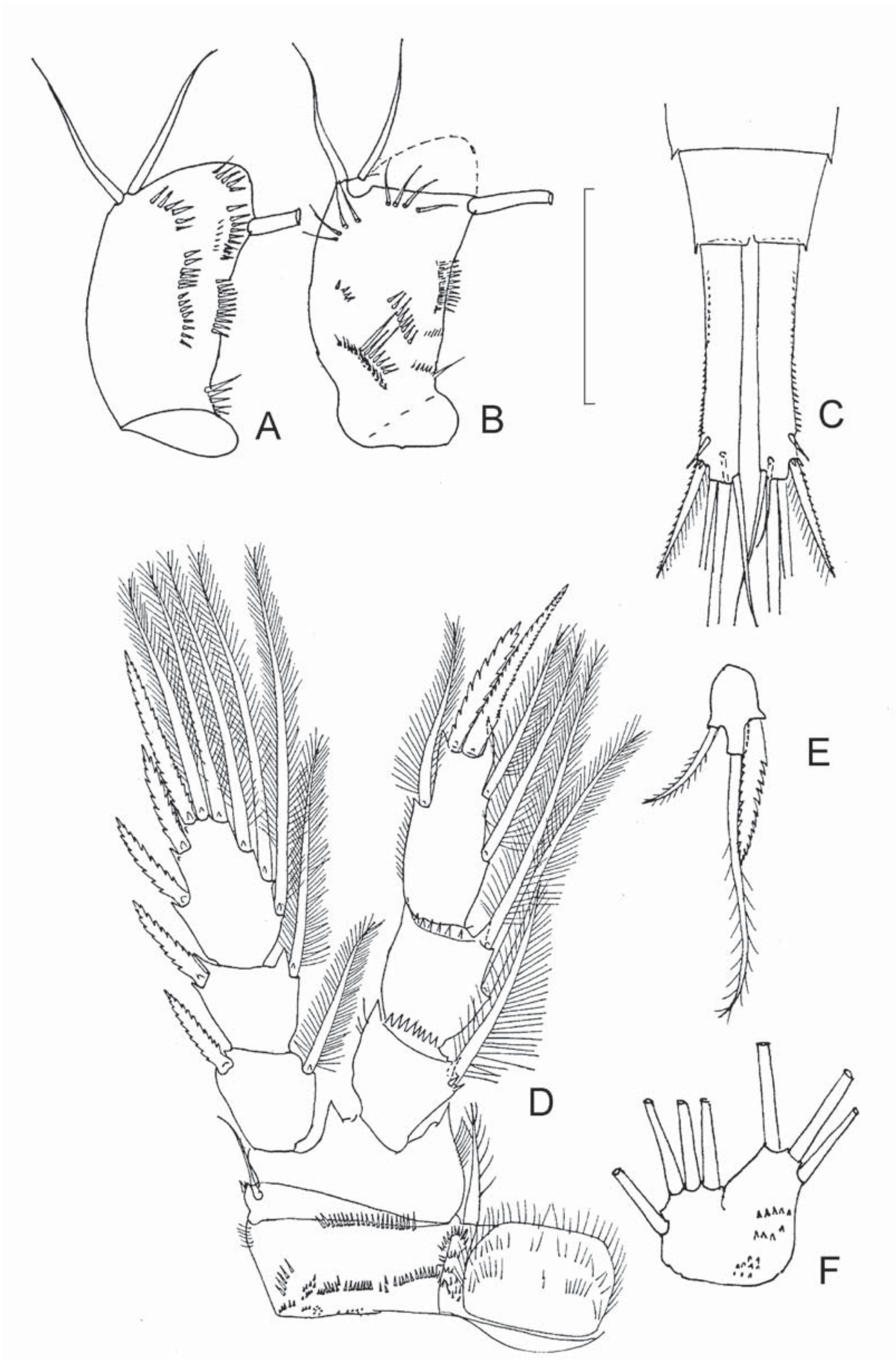


Fig. 5. *Eucyclops pacificus* Ishida, 2000, female, Nam Nao National Park, Thailand: A — basipod of antenna, frontal; B — basipod of antenna, caudal; C, caudal rami, ventral; D — leg 4; E — leg 5; F — maxilar palp. Scale bars: A–B, F — 25 mcm; C— 60 mcm; D–E — 40 mcm.

Рис. 5. *Eucyclops pacificus* Ishida, 2000, самка, Национальный парк Нам Нао, Таиланд: A — базипод антенны, фронтально; B — базипод антенны, каудально; C — каудальные ветви, вентрально; D — ноги 4-й пары, каудально; E — ноги 5-й пары; F — максиларная пальпа. Scale bars: A–B, F — 25 mcm; C — 60 mcm; D–E — 40 mcm.

Table 1. Sampling site description (NE — North East Thailand; NW — North West Thailand, C — Central Thailand)
Таблица 1. Описание мест сбора проб и принятые сокращения (NE — Северо-Восточный Таиланд; NW — Северо-Западный Таиланд, C — Центральный Таиланд)

Number of site	Type of waterbody, biotope	Locality, Sampling Dates	Temperature, C (Salinity)
1	Pond, near shore plankton	Khon Kaen University (NE), 31-01-03	28 (0‰)
2	Stream, among stones and moss	Nam Nao National Parc (NW) 1-02-03	16 (0‰)
4	Irrigative canal, plankton	River Tha Chin (C) 1-02-03	28 (0‰)
5	Irrigative canal near river moth, plankton	River Mae Klon(C) 1-02-03	25 (10‰)
5	Irrigative canal near sea, plankton	Chon Bu Ri Province(C) 1-02-03	27 (27‰)
6	River, near shore among water plant	Nampong River Vicinity of Khon Kaen (NE) 2-02-03	25 (0‰)
7	Pond, near shore plankton	Khon Kaen University (NE), 8-02-03	26(0‰)
8	Pond, near shore plankton	City pond in Khon Kaen (NE) 8-02-03	28 (0‰)
9	Irrigative Pond, near shore plankton	30 km to East from Khon Kaen (NE) 8-02-03	22.5 (0.5‰)
10	Fish Pond	40 km to North East from Khon Kaen (NE) 8-02-03	
11	Reservoir in mountain	Nam Pung Reservoir, The Mecong tributary NE) 8-02-03	24(0‰)
12	Well	Shom Det village(NE) 8-02-03	26(0‰)
13	Well	Ban Bo village(NE) 8-02-03	26(0‰)
14	Temporary pool	Phu Phan National Park(NE) 8-02-03	
15	Natural Lake, among lotos	Lake La Han near Sakhon Nakhon (NE) 8-02-03	23(0‰)
16	Pond, among water plants	Khon Kaen University (NE), 17-02-03	28 (0‰)
17	Pond near fountain	Khon Kaen University (NE), 18-02-03	25 (0‰)
18	Pond-collector of rain water	Khon Kaen University (NE), 19-02-03	26(0‰)
19	Near road ditch	Bangkok (C) 23-02-03	28 (0‰)
20	Irrigative channel	South Thailand*19-11-02	5–8 (0‰)

* a sample from South Thailand was kindly presented by Dr. Pornsilp Pholpunthin
* пробы из Южного Таиланда любезно представлены Доктором Pornsilp Pholpunthin

Genus *Paracyclops*

We did not find *P. fimbriatus* (Fischer, 1853) reported for India, Sri-Lanka, Malaysia, Burma [Dussart & Defaye, 1985] and Thailand [Boonsom, 1984]. Instead we found *P. vagus* Lindberg, 1939, described from India, in several localities of northeast Thailand. S. Karaytug [1999] reported that he did not find Lindberg's type species of *P. vagus* nor samples from India containing this species so he concluded that this species was a younger synonym of *P. fimbriatus* (Fischer, 1853).

We compared *P. vagus* from Thailand with specimens of *P. fimbriatus* from the type locality in the St. Petersburg area, Russia and found that they are different species. We suggest to analyze the antennal basipode, P4 and P5 armaments.

Genus *Ectocyclops*

The only species of the genus we found was *E. polyspinosus* Harada, 1931 described from Taiwan but also known from China and Canada (personal observation of V.A.). As in this species there are some similarities with *E. phaleratus* (Koch, 1838) and *E. rubiscens* (Brady, 1904) cited for Thailand in previous studies. It is possible that these two species were mistaken for *E. polyspinosus* in earlier studies.

Genus *Microcyclops*

M. varicans (G.O. Sars, 1863) was reported for Malaysia, Sri-Lanka and Thailand [Boonsom, 1984]. We found this species only once. All other findings were *M. rubellus* (Lilljeborg, 1901). These two species are closely related and can coexist occasionally in one habitat but usually *M. rubellus* lives at lower latitudes than *M. varicans* (Monchenko, 1975). *Microcyclops* cf. *karevi* is possibly a new species for Thailand but we had only two partly destroyed females at hand.

Genus *Cryptocyclops*

C. bicolor (G.O. Sars, 1863) was found in Thailand in previous studies (Bricker *et al*. 1978) and *C. linjanticus* (Kiefer, 1928) was found to represent similar charters as the above

mentioned *Microcyclops* species. Therefore, it is possible that *C. bicolor* was mistaken in earlier studies for *C. linjanticus.*

Genus *Apocyclops*

Apocyclops sp.

This species was not identified as yet as we only found a male. As for the armament of caudal rami and swimming legs, members of the genus *Apocyclops* are similar to some species of the palearctic genus *Diacyclops*. It is possible that *D. nanus* (reported by Boonsom 1984) from marshlands at higher latitudes in reality was a misinterpretation of an *Apocyclops* species.

Genus *Mesocyclops*

The *Mesocyclops* fauna in S-E Asia is quite rich [Holynska, 2000]. We found 5 species with two of those (*M. pehpiensis* and *M. ogunnus)* as new records for the country. *M. aspericornis* (Daday, 1906) has a pantropical distribution. It was found in Thailand (Sanoamuang 1999) and this year we found it too. *M. thermocyclopoides* Harada, 1931 from SE Asia was found in Taiwan, Birma, Thailand [Boonsom, 1984].

Soon after the description of *M. ferjemurami* Holynska, 2000 in Vietnam it was found in Thailand [Sanoamuang, 2002]. We found *M. pehpiensis* Hu, 1943 and *Mesocyclops ogunnus* Onabamiro, 1957 in ponds of Khon Kaen University and they are most probably not the last new records to be discovered from Thailand.

Genus *Thermocyclops*

This genus is one of the most differentiated taxa of the cyclopid fauna in Thailand. To some extent this depends on poor descriptions of the cosmopolitan *T. crassus* (Fischer, 1853) from the type locality. We found 6 species in northern Thailand. *T. maheensis, T. wolterecki* and *T. rylovy* provides new records for this country.

There are 2 or 3 other *Thermocyclops* species in our samples that do not fit type descriptions known from the literature. A revision of this genus should be an urgent objective for faunistic studies in Thailand in the near future.

Discussion

Biogeographical considerations on cyclopid biodiversity in Thailand Cyclopid biodiversity in continental waters of Thailand comprise several taxa that show various biogeographic and ecological origins. Two representatives of Oithonidae, *Halicyclops* cf. *thermophilus* represent a group of species being of marine origin. In coastal brackish waters of India, China and other geographical areas close to Thailand about 15 species of Cyclopinidae, *Cyclopetta* and Halicyclopinae are known [Defaye and Dussart, 1985]. This group is quite taxonrich in Thailand. We expect the number of species of marine origin to increase within a short period of time.

Several new records comprise species described from or are more common in Africa. With few exceptions all species of the genus *Afrocyclops* inhabit the African Tropics and Subtropics. Hence, *Afrocyclops henrii* n.sp. found in a mountaineous area of Thailand likely represents an element of the African fauna. The same holds for *E. euacanthus* (=*Eucyclops birmanus*) widely distributed in ponds and lakes of Thailand, Burma and for a *Eucyclops birmanus equatorialis* also from Papua-New Guinea. Both, *Tropocyclops tenellus* and *T. confinus* are species that are also described from and are widely distributed in Africa. *Mesocyclops ogunnus* that was described from Africa is now regarded as a species with a wide distribution that includes also Middle and South East Asia, China and Japan [Holynska, 2000].

Eucyclops microdenticulatus, Paracyclops vagus, are also known from Iran and the Indian subcontinent besides Thailand, hence representing the Indo-Iranian fauna. *Ectocyclops arcanus, E. pacificus, E. polyspinosus,* and *T. rylovi* are common in Central and East Asia.

Macrocyclops neuter and Mesocyclops affinis are tropical species. Finally, *Macrocyclops albidus, M. fuscus, M. varicans, T. crassus* were described at first from Europe and are known to be cosmopolitan. In Thailand, they differ in minor details from the type description, but their taxonomical status is still to be defined.

A biogeographical conclusion will be that the continental cyclopoid biodiversity in Thailand turned out to be a fusion of Afro- and Indo-Eurasian elements. This faunistic mixture possibly reflects the hydrological and geological history of this territory and presents additional difficulties for taxonomists in this region. To help them with species identification, we provide herein keys to cyclopoid families, genera and species from Thailand and adjacent areas.

Keys to cyclopoid families, genera and species from Thailand

1. Mandibular palp well developed, of several segments, abdomen longer than the toracic part of the body, genital double somite (GDS) about two times as long as wide . ... Family Oithonidae …2

— Mandibular palp reduced, abdomen equal to or shorter than the thoracic part of body, GDS about as long as wide or even shorter .... Family. Cyclopidae …3

2. Caudal rami relatively short about 2–3 times as long as wide, innermost caudal seta longer than outermost .... Genus *Oithona*
(Several species of marine origin in estuaries of central and southern Thailand)

— Caudal rami at least 5 times as long as wide, innermost caudal seta equal or shorter than outermost seta .... Genus *Limnoithona*
(*L. sinensis* Burckhardt 1912)

3. Rudimentary P5 of big size at distal segment with 4 setae or spines and placed at the outer side of the abdomen, easy to detect from the dorsal side of undissected specimens .... Subfamily Halicyclopinae …4

— Rudimentary P5 of small size with 1–3 setae or spines at distal segment and usually can't be observed from dorsal side in undissected animals 5

4. P5 unisegmented with lateral setae fused to the segment, caudal rami short and usually shorter than two times as long as wide .... Genus *Halicyclops*
H. cf. *thermophylus* (in temporary waters with high conductivity in central Thailand and river mouths in central and southern Thailand)

Table 2. List of Cyclopoida species found in Thailand with indication of sampling sites (see table 1) and reference records. In bold, new records for Thailand

Таблица 2. Список видов циклопов найденных в Таиланде с указанием литературных ссылок на их нахождение и точек сбора проб (см. таблицу 1). Жирным шрифтом выделены новые таксоны для Таиланда.

N	Family, Genus, Species	Number of cites	References of the first record
	Fam. Oithonidae		
	Genus *Limnoithona*		
1	***L. cf. sinensis***	4,20	
	Genus *Oithona.*		
2	***Oithona sp. 1***	4,5,20	
	Fam. Cyclopidae		
	Sub-Family Halicyclopinae		
	Gen. *Halicyclops*		
3	***H. cf. thermophylus***	20	
	Gen. Neocyclops		
4	***Neocyclops sp.***	4,20	
	Sub-Family Eucyclopinae		
	Gen. *Macrocyclops*		
5	***M. fuscus* (Jurine, 1820)**	2,15	
6	***M. albidus* (Jurine, 1820)**	2	
7	***M. neuter* Kiefer, 1931**	2	
	Genus *Eucyclops*		
8	**E. microdenticulatus Lindberg, 1940 ,**	2,9,11,14	
9	***E. arcanus* Alekseev**	15	
10	***E. eucanthus* (Sars 1906) (= E. birmanus Lindberg 1943)**	6,10	
11	***E. pacificus* Ischida 2001**	2,9	
12	*E. cf. serrulatus*	15	Sanoamuang, 1999
13	**Eucyclops sp.**	15	
	Genus *Afrocyclops*		
14	***Afrocyclops henrii* sp.n.**	2	
	Genus Tropocyclops		
15	*T. prasinus* (Fischer, 1860))	2,14,15	Bricker et al. 1978
16	***T. confinus* (Kiefer, 1930)**	14	
17	***T. tenellus* Africa,**	13,	
	Genus *Paracyclops*		
18	*P. fimbriatus* (Fischer, 1853)		Boonsom, 1984
19	***P.affinis* (G.O. Sars,1863*)***	8,9,10,15,17	
20	***P. vagus* Lindberg, 1939**	2,6,10,11,15	
	Genus *Ectocyclops*		
21	*E. phaleratus* (Koch, 1838)		Sanoamuang, 1999
22	***E. polyspinosus* Harada, 1931**	2,20	
23	*E. rubiscens* Brady, 1904		Sanoamuang, 1999
	Genus *Diacyclops*		
24	*D.nanus* (G.O. Sars, 1863)	?	Boonsom, 1984
	Genus *Apocyclops*		
	Apocyclops sp.	20	
25	Genus *Metacyclops*		
26	*Metacyclops sp.1*	20	Sanoamuang, 2002
	Genus *Microcyclops*		
27	*M. varicans (G.O. Sars, 1863)*	12	Bricker et al. 1978
28	***M. rubellus* (Lill., 1901)**	6,16	
29	***Microcyclops cf karvei***	1,15	
	Genus *Cryptocyclops*		
30	*C. bicolor (Sars, 1863)*		Bricker et al. 1978
31	***C. linjanticus (Kiefer, 1928)***	1,15,20	
	Genus *Mesocyclops*		
32	***M. cf. affinis***	15,16,19	
33	*M. aspericornis* (Daday, 1906	6,16,18	Sanoamuang, 1999
34	*M. thermocyclopoides* Harada,	6,8,11,17,19	Boonsom, 1984
35	*M. ferjemurami* Holynska & Nam, 2000		Sanoamuang, 2002

Table 2.
Таблица 2. Продолжение

36	*M. splendidus* Lindberg, 1956		Sanoamuang, 1999
37	***M. pehpiensis* Hu, 1943**	2	
38	***M. ogunnus* Onabamiro, 1957**	1,6,	
	Genus *Thermocyclops*		
39	*T. crassus (Fischer, 1853)*		Boonsom, 1984
40	*T. taihokuensis (Harada, 1931)*		Sanoamuang, 1999
41	*T. decipiens (Kiefer, 1926)*	15	Sanoamuang, 1999
42	***T. woltereckі* Kiefer, 1938**	15	
43 ***44-49***	***T. maheensis* Lindberg,** 1941 ***T.rylovi (Smirnov, 1929)*** ***Thermocyclops* sp.**	6 6 8,11,17,19	

— P5 three segmented, caudal rami usually more than two times as long as wide .... Genus *Neocyclops* (*Neocyclops* cf. *solinarium* estuaries in central and southern Thailand)
5. Rudimentary P5 with three appendices at distal segment .... Subfamily Eucyclopinae ... 6
— P5 with 1–2 appendices at distal segment....................... .... Subfamily Cyclopinae ... 10
6. Rudimentary P5 is 2-segmented .... Genus *Macrocyclops*
— P5 is 1-segmented or even fused to 5th toracic somite 7
7. P5 as narrow plate fused to 5th toracic somite, caudal rami with several rows of spinules dorsally .... Genus *Ectocyclops*
— P5 1-segmented and well separated from the 5th toracic somite, caudal rami without such rows 8
8. Internal angle of P4 basis sharply produced .... Genus *Eucyclops*
— This angle rounded 9
9. Furcal rami less than 4 times as long as wide, A1 reaching end of toracozone .... Genus *Tropocyclops*
— Furcal rami about 5 times as long as wide, A1 shorter... .... Genus *Afrocyclops* *(A. henrii* n.sp. from a mountain stream in Nam Nao Nathional Park, central Thailand*)*
10. P5 is 2-segmented 11
— P5 1-segmented 14
11. Distal segment of P5 with long setae and a short spine 12
— This segment with two long setae 13
12. Inner spine P5 very short, less than half of segment length, caudal rami with hairs on inner edge, females about 2 mm in length .... Genus *Megacyclops* (*M. viridis* was found by V.A. in a sample from the Malaysian peninsula near Singapore in a shallow bog-like pond — hence, it can be expected to occur at least in southern Thailand as well)
— Inner spine of P5 not less longer than the segment itself, caudal rami naked, size of females about 1 mm .... Genus *Diacyclops* (only one reference in Thailand for *D. nanus* — which is a palearctic form and likely to be a misidentification)
13. Inner spine of P5 inserted in the middle of the distal segment ....Genus *Mesocyclops*
— This spine inserted near the outer seta ....Genus *Thermocyclops*
14. Caudal rami with lateral seta near the middle of the outer margin 15
— Caudal rami with lateral seta inserting in the last third of the outer margin or even more distally 16
15. Distal (single) segment of P5 longer than wide with long seta and small spine terminally ...... Genus *Metacyclops*
This segment wider than long with seta and small spine at opposite sides of the segment .... Genus *Apocyclops*
16. Inner distal spine of endopod P4 not more than two times as long as outer spine ....Genus *Microcyclops*
— This spine at least three times as long as outer spine .... Genus *Cryptocyclops*

Genus *Macrocyclops*

1. Caudal rami naked, innermost seta about 3 times as long as wide, distal segment of A1 with smooth membrane . ... *M. albidus* (Jurine, 1820)
— Caudal rami with hairs, innermost seta about 2 times as long as wide, distal segment of A1 with rough dents .. 2
2. Hairs on caudal rami dense, dorsal seta about as long as ramus .... *M. fuscus* (Jurine, 1820)
— Hairs are rare, dorsal seta about twice as long as ramus ....*M. neuter* Kiefer, 1931

Genus *Paracyclops*

1. A1 is 11-segmented, distal segment of Exp P3 with 3 spines .... *P. affinis* (G.O. Sars, 1863)
— A1 is 8 segmented, distal segment of Exp P3 with 4 spines 2
2. Innermost caudal seta equal or a bit longer than outermost seta, caudal rami with short transversal row of spines, inner spine of P5 about twice as long as adjacent seta .. ..*P. fimbriatus* (Fischer, 1853)
— Innermost caudal seta about 1.2 times as long as outermost seta, rami with longer spine row extending the inner edge of caudal rami, inner spine of P5 and adjacent seta about the same length .... *P. vagus* Lindberg, 1939

Genus *Ectocyclops*

1. A1 is 11-segmented .... *E.* cf. *polyspinosus* Harada, 1931
— A1 is 10-segmented 2
2. Inner spine P5 much longer than adjacent 2 setae ....*E. rubiscens* Brady, 1904

— This spine is of equal length to adjacent setae .... *E. phaleratus* (Koch, 1838)

Genus *Tropocyclops*

1. Dorsal seta two or more times as long as caudal ramus .. .. *T. tenellus* (G.O. Sars, 1909)
— This seta equal or slightly longer than caudal ramus 2
2. Innermost caudal seta equal in length or longer than outmost seta, spinular formula of swimming legs: 3/4/4/3 .... *T. prasinus* complex (Includes more than 10 subspecies in the tropics)
— This seta shorter than outermost seta, spine formula 3/4/4/3 .... *T. confinus* Kiefer, 1930

Genus *Eucyclops*

1. Innermost caudal seta about 1.5–1.8 times as long as outmost seta, caudal serrula with denticles of different sizes, in P5 inner spine not strong and clear shorter of outer seta .... *E. eucanthus* (Sars 1906) = *E. birmanus* Lindberg, 1949
— Innermost seta 1.1–1.5 times as long as outmost seta, caudal serrula with denticles more or less equal in size, in P5 inner spine strong and not shorter than outer seta 2
2. Caudal setae partly reduced, inner- and outmost setae subequal in length, inner side of P4 basis hairless .... *E. arcanus* Alekseev, 1989
— Setules occupy most of the outer edge of the caudal rami, innermost seta about 1,2–1.5 times as long as outmost seta, inner side of P4 basis with hairs 3
3. Caudal rami less than 4 times as long as wide and widely divergent, in A1 3 distal segment with tiny denticles on hyaline membraine clear seen without oil immersion ... . *E. microdenticulatus* Lindberg, 1940
— Caudal rami longer than 4 times as long as wide and only slightly divergent or even parallel, 3 distal segments of A1 with a smooth hyaline membrane .... *E. serrulatus* group (includes more than 5 species in tropical Thailand (*E. pacificus* and *E.* cf *serrulatus* are widely destributed)

Genus *Microcyclops*

1. Caudal rami with notches in proximal part .... *M.* cf *carevi*
— Caudal rami without notches in proximal part 2
2. Caudal rami elongated 3.4–4 times as long as wide, antennula 12-segmented .... *M. varicans* (Sars, 1863)
— Caudal rami 2.5–3 times as long as wide, antennula 11-segmented .... *M. rubellus* (Lilljeborg, 1901)

Genus *Cryptocyclops*

1. Caudal rami not less than 3.8 times as long as wide, innermost setae as long as caudal branch .... *C. bicolor* (Sars, 1863)
— Caudal rami less than 3.6 times as long as wide, the innermost setae longer than the caudal branch .... *C. linjanticus* (Kiefer, 1928)

Genus *Mesocyclops*

1. Inner portion of basis P1 with seta, P5 and caudal rami without hairs .... *M. annae*-group ... 2
— This part of P1 without seta 3
2. Inner part of basis P4 with hairs, outgrowth of connective plate less than ¼ of inner part of basis P4 .... *M. splendidus* Lindberg, 1956 = *M. pseudoannae* Van de Velde, 1987
— Inner part of basis P4 hairless, outgrowth of connective plate about 1/3 of inner part of P4 basis .... *M. annae* Kiefer, 1930
3. P5 and caudal ramus without hairs .... *M. leuckarti*-group ... 4
— Body with patterns of hairs 10
4. Dorsal seta of caudal rami very long, practically equal to innermost seta and 2 times as long as outermost seta ... . *M. tobae* Kiefer, 1933
— This seta matches outermost seta in length 5
5. Coxal spine of P4 very short not reaching distal end of inner part of basis .... *M. restrictus* Dussart & Fernando 1985
— This spine of normal length and reaching far beyond distal end of inner part of basipode 6
6. Innermost seta of caudal rami very short about 1.3 times as long as outermost seta; in P5 inner spine longer than distal seta 7
— This seta at least twice as long as outermost seta, inner spine of P5 longer or equal to distal seta 8
7. In genital double somite (GDS) distal surface covered with small spinules, the same spinules can be found on the caudal rami .... *M. yenae* Holynska, 1998
— Both GDS and caudal rami without such spinules .... *M. brevisetosus* Dussart & Sarnita, 1987
8. In P4 inner side of basipod with hairs .... *M. ferjemurami* Holynska, 2000
— Inner side of P4 basis without hairs 9
9. *Receptaculum seminis* with two circular pores in the middle .... *M. papuensis* Van de Velde, 1987 = *M. borneoensis* Dussart & Fernando 1988
— *Receptaculum seminis* with only one (sometimes no) circular pore .... *M. pehpiensis* Hu, 1943
10. Both P5 and inner side of caudal rami with hairs .... *M. aspericornis*-group ... 11
— Body with only one pattern of hairs 14
11. Caudal rami with very short and widely dispersed hairs mainly on proximal half of inner margins 12
— Caudal rami with long and dense hairs homogeneously distributed along the inner margins 13
12. Hairs occupy not more than 1/3 of proximal part of branches; in RS pore canal with narrow loop (1:2) .... *M. microlasius* Kiefer, 1981
— Hairs occupy about half of proximal part of branches; in RS pore canal with wide loop (1:1) .... *M. pilosus* Kiefer, 1930
13. P4 intercoxal membrane without hairs ....*M. aspericornis* (Daday, 1906)
— This membrane with hairs ....*M. dadayi* Holynska, 1997
14. Caudal rami with hairs on inner edges .... *M. pseudospinosus*-group (one species from Java: *M. pseudospinosus* Dussart & Fernando, 1988)
— Only P5 with hairs on inner edges ....*M. thermocyclopoides*-group ... 15
15. P4 distal segment of endopod with clear seen denticles on both edges .... *M. guangxiensis* Reid & Kai, 1992
— This segment without such denticles 16
16. A2 basis on caudal surface with group of large spinules next to implantation of inner setae 17

— A2 basis on caudal surface without such group of large spinules, no such hairs on GDS 18
17. Maxillar palp with groups of clearly visible denticles, females of small size 0.9–1.2 mm .... *M. ogunnus* Onabamiro, 1957
— Maxillar palp unfurnished, females of 1.3–1.6 mm .... *M. thermocyclopoides* Harada, 1931
18. A2 basis on caudal surface with group of small spinules between the proximal oblique and longitudinal spinules rows .... *M. isabellae* Dussart & Fernando 1988
— Spinule group absent 19
19. A1 with groups of small spinules on 6–13 segments, pore canal straight .... *M. affinis* Van de Velde 1987
— Famales without such signs 20
20. Outermost seta of caudal rami without small spinules near insertion plane .... *M. woutersi* Van de Velde, 1987
— This seta with such spinules .... *M. dissimilis* Defay & Kawabata, 1993 (= *M. parentium* Holynska, 1997)

Genus *Thermocyclops*

1. Genital double somite (GDS) very wide, length/width ratio =0.75; P4 distal segment with endopod less than twice as long as wide .... *T. tinctus* Lindberg, 1936
— GDS and distal segment of endopod P4 longer 2
2. Lateral setae insert midlength of caudal rami margin 3
— Lateral setae insert at about the last third of caudal rami length or even closer to its distal end 10
3. Inner medial caudal seta very short, about 2.5 times as long as caudal rami, adult females of small size (0.6–0.65 mm) .... *T. minutus* (Lowndes, 1934)
— This seta longer, adult females at least 0.75 mm or longer 4
4. Dorsal seta of caudal rami distinctly shorter than innermost seta 5
— Dorsal and innermost setae of caudal rami more or less equal in length 6
5. End P4 inner distal spine longer than End .... *T. maheensis* Lindberg, 1941
— This spine shorter than End .... *T. incisus* Kiefer, 1932
6. Distal spines of End P4 practically equal in length .... *T. inversus* Kiefer, 1936
— These spines different in length 7
7. Inner distal spine of End P4 not more than twice as long as outer spine .... *T. tenuis* (Marsh, 1910)
— Inner spine of End P4 at least 2.5 times as long as outer spine 8
8. Caudal rami dorsal seta short, about twice as short as innermost seta, connective membrane of coxa P4 with denticles on outgrowths .... *T. oithonoides* (G.O. Sars, 1863)
— This seta about as long as innermost seta, the outgrowths naked 9
9. Inner spine P5 shorter than apical seta .... *T. iwoensis* Onabamiro, 1952
— This spine longer than apical seta .... *T. emini* (Mrazek, 1895)
10. Caudal rami long, 3.8–4.6 as long as wide 11
— Caudal rami shorter 14
11. Distal spines of End P4 equal in size 12
— These spines different in length 13
12. Outermost seta longer or equal in length to caudal rami, *receptaculum seminis* with a very short medial part .... *T. schmeili* (Poppei & Mrazek, 1895)
— Outermost seta of caudal rami shorter than ramus, *receptaculum seminis* of peculiar structure .... *T. kawamurai* Kikuchi, 1940
13. Connective membrane of coxopodite P4 with small smooth outgrowths .... *T. inopinus* (Kiefer, 1926)
— This membrane with tiny denticles on outgrowths .... *T. operculifer* Kiefer, 1930 (*T. o. aberrans* Lindberg, 1952 differed from the type form with shorter caudal rami and RS construction)
14. Caudal rami of average length, 2.5–3.3 as long as wide if less than innermost caudal seta, more than 2.5 times as long as outermost seta 15
— Caudal rami 1.9–2.3 as long as wide, innermost seta less than 2.3 times as long as outermost seta 20
15. In P4 inner spine shorter than outer spine .... *T. dybowski* (Lande, 1896)
— P4 inner spine longer than outer spine 16
16. Inner distal spine of End P4 1.8–2.8 as long as outer spine, in *receptaculum seminis* lateral arms straight or slightly curved backwards 17
— This spine at least 2.5–3 times as long as outer spine in *receptaculum seminis* lateral arms strongly curved backwards 19
17. Inner distal spine of End P4 clearly bent in its medial part, length/width proportion of the segment more than 3, caudal rami 3–3.4 times as long as wide 18
— This spine straight or slightly bent in its proximal part, length/width proportion of the segment not more than 3; caudal rami 2–2.5 times as long as wide, P5 inner spine not longer than outer seta ...... *T. crassus* (Fischer, 1853)
18. P4 connective membrane with dense thin hairs or denticles on outgrowths, A1 reaching only distal end of cephalosome .... *T. rylovi* (Smirnov, 1928)
— P4 connective membrane with rough dents on outgrowths, A1 reaching distal end of the first free somite, in P5 inner spine longer than outer seta .... *T. decipiens* Kiefer, 1929
19. Inner distal spine of End P4 about 2.8–3.2 times as long as outer spine, connective membrane of coxopod of P4 with relatively rough denticles on outgrowths; caudal rami about 2 times as long as wide . *T. oblongatus* (G.O. Sars, 1927)
— Inner distal spine of End P4 about 3.5–4.2 times as long as outer spine, connective membrane of coxopod of P4 with fine denticles on outgrowths, caudal rami about 2 times as long as wide .... *T. taihokuensis* Harada, 1931
20. Inner distal spine of End P4 about 1.6–2.1 times as long as outer spine .... *T. neglectus* (G.O. Sars, 1909)
— This spine 3–4 times as long as outer spine .... *T. consimilis* Kiefer, 1934

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